Summary of Recommended Changes to the FITS Standard Document, Version 2.1b

FITS Technical Panel

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This document summarized the main recommendations of the FITS technical panel that was appointed by the IAU FITS Working Group to propose ways to update and clarify the FITS Standard document. These recommended changes have been divided below into 3 categories:

- changes that affect basic FITS requirements or recommendations,
- significant changes to clarify various sections of the document, but that do not affect basic FITS requirements, and
- other more minor editorial and typographical changes.

The section numbers shown below refer to the sections in the new draft 3.0 version of the document.

1 Changes to FITS Requirements or Recommendations

This section lists the recommendations that modify the basic rules of FITS by adding or removing requirements or recommendations.

1. Section 3.4.1 - Add a recommendation, taken from the Generalized Extensions FITS paper, that new extension types should only be created when existing extensions types are not adequate.

2. Section 3.4.1.3 - Delete the requirement that 'No extension shall be constructed that invalidates existing FITS files', because a) this appears to be a logical impossibility, and b) in any case, it is unnecessary because it is already covered by the prime requirement that existing FITS files shall remain valid in the future (given in section 3.7).

3. Section 3.4.2 - Delete the requirement that each standard extension shall have a unique name because it repeats the same requirement given immediately above it in 3.4.1.1.

4. Section 3.5 - Deprecate 'Special records'. The provision of special records at the end of FITS files has generally been regarded as an 'escape clause' that allows new FITS data structures to be developed to support future needs. The technical panel believes, however, that this authority to invent new FITS formats needs to be carefully controlled, and that it is not in the best interest of the astronomical community to allow individual groups or projects to unilaterally invent new types of FITS files without the close coordination and support of the IAUFWG. Also, the existing 'conforming extensions' data structure appears to be sufficient to meet most future needs. Therefore, it is recommended that the provision for special records be deprecated. In any case, the IAUFWG still has the authority to define any new FITS structures that might be needed in the future, as is noted in the proposed new footnote to this section.

The technical panel had considered stronger wording (instead of 'deprecate') that would *prohibit* any further use of special records, but decided that more public discussion of this issue was needed before making such a recommendation.

5. Section 3.7 - Add the requirement that 'Existing FITS files that conformed to the latest version of the standard at the time the files were created are expressly exempt from any new requirements imposed by subsequent versions of the standard'. The is necessary in particular to avoid the possibility that new reserved keywords could invalidate older FITS files that used these same keyword names for entirely different purposes. For example, the WCS conventions have introduced more than 100 new reserved keywords, and it is conceivable that some older FITS files have used these keywords in other ways.

6. Section 4.1.1 - Add a new recommendation that the order of keywords in an HDU be preserved during data processing operations. There are common conventions in use by the FITS community that attach particular significance to the order of keywords (e.g., the order of COMMENT or HISTORY keywords), so software should try to preserve the order if possible.

7. Section 4.1.2.3 - Add a new requirement that keywords that have a value shall not be repeated in a header. This is a 'common sense' requirement that should be explicitly stated in the standard. As far as the technical panel is aware, there are no existing FITS files that intentionally repeat a keyword with a value multiple times.

8. Section 4.2.1 - Remove the requirement that fixed-format character keyword values must be padded with spaces to at least 8 characters in length, except for the value of the XTENSION keyword, e.g. `'IMAGE   '` and `'TABLE   '`, which must continue to be padded for consistency with past usage. This 8-character minimum was mandated in the original FITS definition paper to 'simplify the decoding of parameters on modest computers'. Having enough computer resources to decode a free-format keyword value is certainly no longer an issue, and if anything, having to enforce this minimum 8-character length requirement only serves to complicate software that reads or writes character keyword values.

9. Section 4.4.1.1 - Add to the definition of the BITPIX keyword that 'Writers of FITS arrays should select a BITPIX data type appropriate to the form, range of values, and accuracy of the data in the array.' This same wording has been added to section 7.3.3.1 regarding the choice of table column formats. The main purpose of this added text is to address concerns that FITS writers might misuse the newly added 64-bit integer data format for data that do not require the extended range of values.

10. Section 4.4.1.2 - XTENSION keyword - Emphasize that new extension type names must be registered with the IAUFWG. This requirement is also stated in the previous chapter (section 3.4.1.1) but is worth repeating for emphasis here in the definition of the XTENSION keyword.

11. Section 4.4.1.2 - Add a requirement that the PCOUNT and GCOUNT keywords must immediately follow the last NAXISn keyword in all conforming extensions, rather than just appear somewhere in the header after the NAXISn keyword. This is already a requirement for the 3 standard extension types, so for consistency, this requirement also should apply to any new extension types that are developed in the future.

12. Section 4.4.1.2 - Demote the EXTEND keyword from a mandatory keyword to a reserved keyword (i.e., move it from section 4.4.1.2 to section 4.4.2). As a consequence, the EXTEND keyword will no longer be required in the primary header of FITS files that have extensions. The technical panel believes that this keyword serves no useful purpose as it is currently defined and should no longer be required (similar to the deprecated BLOCKED keyword requirement).

    Similarly, remove the sentences that state that the primary array must contain the EXTEND keyword if the FITS file contains one of the standard extensions in sections 7.1, 7.2, and 7.3.

13. Section 4.4.2.3, REFERENC keyword - Add a recommendation that the bibliographic code string, as used by the ADS, should be included in the value of this keyword. The bibcode string is a recognized standard used by the astronomical community.

14. Section 4.4.2.6 - Remove the restriction that the EXTNAME/ EXTVER/ EXTLEVEL keywords must not be used in the primary array. The "EXT" in these keyword names stands for "EXTENSION", hence, the previous FITS technical panel ruled that these keywords should not be used in the primary array since it is not an extension. This prohibition has been routinely ignored in practice (e.g., if an image extension is copied into a FITS primary array, the EXTNAME keyword is not usually deleted). To compound the confusion, some groups have adopted a new set of keywords (HDUNAME, HDUVER, and HDULEVEL) that can be used in all types of HDUs.

    The panel believes that the simplest solution to this problem is to remove the prohibition on using these keywords in the primary array. The alternate solution, to add a 2nd set of reserved keywords (HDUNAME, etc) to the standard, and perhaps deprecate the current set of keywords, would likely cause more disruption to existing software packages.

15. Section 4.4.3.1 - Remove the restriction that a keyword shall not specify the presence of a specific extension, and shall not refer to an explicit block size. These restrictions seem to serve no useful purpose. These rules are also largely unenforceable by FITS verification software.

16. Sections 7.2.2 and 7.3.2, TTYPEn keyword - Add a strong recommendation in these 2 sections that every field of ASCII and binary tables 'should' be assigned a unique name with the TTYPEn keyword. The original ASCII table definition paper stated that this keyword is 'strongly recommended', so the lack of any recommendation in the previous NOST version of the standard that this keyword should be present seems conspicuous by its absence. In the technical panel's experience, there are few, if any, existing tables that do not already meet this requirement.

17. Sections 7.2.2 and 7.3.2, TTYPEn keyword - Add the hyphen to the list of recommended characters in column names (in addition to letters, numbers, and the underscore character). for consistency with the list of allowed characters in a keyword name. The previous recommendation to avoid using the hyphen in column names has been widely ignored anyway.

18. Section 7.2.4 - Add a statement that use of overlapping fields in ASCII tables is 'not recommended'.

19. Section 7.2.5 - Disallow (not just deprecate) embedded space characters within numeric ASCII table fields. This usage is very likely to cause confusion and misinterpretation of the data, therefore should not be permitted. As far as the technical panel is aware, there are no existing FITS files that have used this feature.

20. Section 7.2.5 - Deprecate the use of implicit decimal points within floating point ASCII table fields. This usage is likely to cause confusion and misinterpretation of the data, so further use should be discouraged. The motivation for allowing implied decimal points within Fortran was presumably to save space when using 80-column punched cards, but this space savings is insignificant for FITS users.

    The technical panel had considered stronger wording (instead of 'deprecate') that would *prohibit* any further use of implicit decimal points, but decided that more public discussion of this issue was needed before making such a recommendation.

21. Section 7.3.3.2 - Reword this short section to be more emphatic about the intended use of the heap data area. The current ambivalent wording (i.e. "One use for this data area is described in section ...") seems to be left over from when the variable-length array convention was only described in an unofficial appendix. Now that the variable-length array convention has been officially approved by the IAUFWG (in 2005) this section should more definitely state how the heap is intended to be used.

    The technical panel also suggests deleting the last sentence of this section ("This does not preclude other uses for these bytes.") because it is redundant to state this explicitly, even though it is a valid statement This statement is implicitly true, and the same statement could also be applied to other FITS data structures.

22. Section 8 - This new section describing World Coordinate Systems has been added. The material for this section has been taken from the 3 published WCS papers which have been officially approved as part of the FITS Standard by the IAUFWG.

2 Other Individual Recommendations

This section lists other recommended changes to individual sections of the standard. These recommendations do not affect the requirements of a FITS file. Minor editorial changes that are made simply to clarify the text or fix typographical errors are not listed here. The section number shown below refer to the sections in the new draft 3.0 version of the document.

1. Preface (of version 2.1b) - Delete the preface that discusses the NOST. This discussion of the rules of the NOST approval process is no longer relevant. The list of members of the various technical panels is retained in the new Acknowledgments section 1.3.

    After this revised standard is formally approved, the technical panel recommends that a new preface be added to the beginning of the document to describe the source of authority (i.e., the IAU, Commission 5), the review process that lead to the final document, and any other pertinent information about the document.

2. Section 1, Introduction - Replace the previous Introduction and Overview sections with a new Introduction section that includes a brief history of FITS, a history of previous versions of the document (copied in part from the Appendix J of the previous version),

and an acknowledgments subsection that lists the members of the current and previous technical panels.

3. Move the References section (which used to be Section 2) to the Bibliography at the end of the document. Modify the format of the references to be more consistent with current scientific journals. Add references to the 3 published WCS papers, The HEALPix projection paper, the NOST standard publication by Hanisch et al., the RFC 2119 on key words (e.g., ‘must’, ‘should’, etc.), and the RFC 4047 on FITS MIME types. Update the Fortran reference to the current Fortran 2003 standard. Delete the unused references to the Hierarchical grouping convention, and the IUE FITS format document.

4. Section 2.2 - Add the following new defined terms:

   - ASCII digit
   - big endian
   - character string
   - data block
   - FITS block
   - FITS Support Office
   - header block
   - keyword record
   - MEF
   - random group
   - SIF

   Delete the following terms

   - DAT
   - extension name (replaced by extension type name)
   - extension type (replaced by extension type name)
   - GSFC
   - IUE
   - matrix
   - picture element (incorporate into the ‘pixel’ definition)
   - reference point
   - type name (replace by ‘extension type name’)
   - valid value

5. Section 3.1 Add an informational statement to the effect that the standard does not place any limit of the size of a FITS file or an individual HDU, but note that some software systems may have size restrictions.

6. Section 3.3.2 - Add the clarification that the FITS array order is the same as for Fortran arrays.

7. Section 3.6 - Simplify and clarify the discussion of physical blocking, and delete references to obsolete types of tape media.

8. Section 3.7 - Move this important 'Once FITS - Always FITS' requirement from its previous location by itself in chapter 9 to section 3.7 where it is more logically connected to the previous subsections.

9. Section 4.1.2.3 - Add the clarification that keywords without an equal sign and space in bytes 9 and 10 should be interpreted as containing comments, but that this does not preclude conventions that interpret the content of such keywords in other ways (e.g., in the HIERARCH and CONTINUE keyword conventions).

10. Sections 4.2.3 and 4.2.4 - Add statements that the standard places no restriction on the magnitude or precision of keyword values, but note that some software systems are limited in the range of keyword values that can be supported.

11. Section 4.3 - This units discussion and tables have been copied from the WCS paper I.

12. Section 4.4.1.1 - Add table 4.7 that shows an example of a simple primary array header.

13. Section 4.4.1.2 - PCOUNT and GCOUNT - Expand the previous generic definitions to also state how these keywords must be used in existing FITS structures.

14. Section 4.4.2.1, DATE keyword - Remove the obsolete statements that "Starting January 1, 2000, the following format shall be used. FITS writers should commence writing the value of the DATE keyword in this format starting January 1, 1999 and before January 1, 2000."

15. Section 4.4.2.1, BLOCKED keyword - Emphasize that this keyword is deprecated.

16. Section 4.4.2.2, DATE-OBS keyword - Clarify the usage of TCG, TCB, and TDB time systems (suggested by Pat Wallace).

17. Section 4.4.2.2, EQUINOX keyword - Clarify the meaning of EQUINOX = 2000 (suggested by Pat Wallace).

18. Section 4.4.2.2 EPOCH keyword - Emphasize that this keyword is deprecated.

19. Section 4.4.2.5 - Expand and clarify the definitions of the BSCALE, BZERO, and BLANK keywords, especially in regard to their use with unsigned integers.

20. Section 4.4.2.5 - Move the WCS keyword discussion into a new section 8.

21. Section 5.2.5 - Expand and clarify how unsigned integers are represented in FITS files.

22. Section 7, Standard Extensions - reorder the subsections so that IMAGE extensions are discussed first, followed by the 2 types of table extensions.

23. Section 7.1.2 - Delete this short section on units usage in IMAGE extensions keywords because this requirement is already stated in section 4.3. This section is also inconsistent with the discussions of ASCII table and binary table extensions which do not repeat this same requirement.

24. Section 7.2.2 - Add the TDISPn keyword to the list of reserved keywords in ASCII tables, for consistency with binary tables.

25. Section 7.2.4 - Add the informational statement that a common convention is to include a space character between fields of an ASCII table (as was recommended in the original ASCII table definition paper). Also clarify that ASCII control characters must not be used within defined fields in an ASCII table but may be used before, after, or between the defined fields.

26. Section 7.2.5 - Add a statement that the standard places no restriction on the magnitude or precision of numeric values in ASCII tables, but note that some software systems are limited in the range of keyword values that can be supported.

27. Section 7.3.2 - Expand and clarify the discussion of the TSCALn, TZEROn, and TNULLn keywords, especially in regard to their use with unsigned integers.

28. Section 7.3.4 - Clarify that the minus sign only applies when the integer is displayed as a decimal number, and not when displaying as a binary, octal or hexadecimal value.

29. Delete the previous Appendix B, Proposed Binary Table Convention. - This appendix describes a proposed convention for arrays of strings in a binary table column that is not appropriate to include in the FITS Standard, and should perhaps be submitted to the Registry of FITS conventions instead.

30. Delete the previous Appendix C, Implementation on Physical Media - This discussion of how to implement FITS on magnetic tape is obsolete. Section 3.6 of the standard contains all the relevant information about supporting sequential media.

31. Appendix B, Time Scale Specification (Formerly Appendix D) - Make a number of clarifications suggested by Pat Wallace. (This material might eventually be incorporated into a future WCS paper on time coordinates).

32. Delete the previous Appendix E, Differences from IAU-endorsed Publications - This material is out of date and is at most only of historical interest. This information should be preserved for future reference, perhaps on the FITS support office web site.

33. Appendix C (formerly Appendix F), Summary of Keywords - Move the EXTEND keyword from table C.1 (mandatory) to C.2 (reserved). Add TDISPn to reserved keyword list for ASCII tables. Delete the WCS keywords from table C.2 because the much more extensive set of WCS keyword is now discussed in Section 8.

34. Appendix F (formerly Appendix I), Reserved Extension Type Names - Replace and update this section with material taken from the FITS Support Office web site. The VGROUP name is no longer listed because its proposed use has been withdrawn.

35. Appendix G - A new section on MIME types has been added for informational purposes. This material is taken verbatim from the RFC 4047.

36. Delete Appendix J - the table of previous versions of the Standard is now included in the Introduction, in table 1.2

3 Other Global Recommendations

This section lists relatively minor recommended changes to clarify the text that affect multiple sections of the document. These changes are editorial or typographical in nature and are not intended to affect the interpretation of FITS requirements.

1. Display the words 'must', 'shall', 'should', 'may', 'recommended', and 'optional' in italic font to emphasis that they have a precisely defined meaning.

2. Replace all instances of double quote characters with single quotes for consistency throughout the document.

3. Hyphenate the words floating-point, fixed-format, free-format, right-justified, and multi-dimensional.

4. Replace 'twos-complement' with 'two's complement'. Google searches of the web indicate that the latter term is used much more frequently.

5. Replace the dash between two numbers with the word 'through' or 'to' (e.g. '1 through 999' instead of '1–999').

6. Replace the term 'ASCII blank' with 'ASCII space'.

7. Replace the obsolete term 'card image' with 'keyword record'. Similarly, change the string 'card_image' to 'keyword_record' throughout appendix A,.

8. Replace the term 'column' with 'byte' when referring to a position in a 80-character keyword record.

9. Replace the term 'logical record' with 'FITS block' as a more specific term to refer to the 2880-byte building blocks of FITS. Also use the new terms 'header block' and 'data block' to refer to the 2880-byte components of the header and data areas of an HDU, respectively. 'FITS block' is a general term referring to either a 'header block' or a 'data block'.

10. Introduce the term 'big endian' to refer to the byte order in numerical FITS data.

11. Add the clarification that 'ASCII text' means the restricted set of ASCII characters, decimal 32 to 126.

12. Add the corresponding decimal ASCII character codes in most cases where the hexadecimal codes are given.

13. Add statements to emphasize that ASCII control characters must not occur in a keyword record or a header block.

14. Replace instances of 'ANSI FORTRAN 77' with the generic word 'Fortran', because all current versions of Fortran (77, 90, 95, 2003) are equivalent as far as FITS usage is concerned. Update the Fortran reference in the Bibliography to the ISO Fortran 2003 definition document.

15. Consistently use the term 'main data table' to refer to fixed length binary table data area, and the term 'supplemental data area' to refer to the heap.

16. Replace the term 'record' with 'row' to refer to a row of a binary table (mainly in the section describing variable length arrays).